

changes brought about by differing numbers of simultaneously interfering co-channel base stations, i.e. by ignoring secondary effects. And, from these results, one can estimate the spectral efficiency gains resulting from the reduced co-channel protection ratios that all LM systems need relative to all FM systems. The table below presents these results.

Table 2

Co-Channel Interference Protection	Co-Channel Protection Ratio*	Relative Spectral Efficiency (VC/MHz/Mi ²)
FM-to-FM Systems (12.5 kHz)	12 dB	100% (Reference)
LM-to-LM Systems (No pilot tone frequency offsets)	10 dB	126%
LM-to-LM Systems (With stable pilot tone frequency offsets of approximately 100 Hz)	6 dB	200%

* This degradation is based on a 6 dB decrease from 20 dB SINAD to 14 dB SINAD of the victim receiver.

It should be emphasized that these substantial increases in spectrum efficiency due to closer geographic spacing are not considered in the balance of the report where we estimate the economic impacts of going to 5 kHz channel spacing as advocated by Securicor.

IV. Value of the Additional Spectrum Created by the More Efficient Channelization Plan

Using the results we obtained in Section III, the results that the Commission has recently obtained in auctioning both narrowband and broadband PCS and IVDS spectrum, and other measures, it is possible to estimate the value of the additional spectrum created by adoption of the more efficient channelization plan advocated by Securicor.

The recent 1.9 GHz band PCS spectrum auctions brought in a total of approximately \$7.7 billion for 60 MHz of MTA spectrum on a nationwide basis. This amounts to \$128.3 million per MHz of spectrum. The 900 MHz band PCS spectrum auction netted the treasury \$617 million for ten nationwide licenses for a total of 787.5 kHz of spectrum. This is equivalent to \$783 million per MHz of spectrum. The regional 900 MHz band PCS spectrum auction brought in a total of \$488.7 million for 450 kHz of spectrum on a nationwide basis, amounting to \$1.086 billion per MHz of spectrum. Finally, the 218 MHz band IVDS spectrum auction amounts totaled \$248.7 million for 1 MHz of spectrum on a nationwide basis. Table 3 presents some estimates, based on these spectrum auctions, of the value of the 5.88 MHz of extra spectrum created by using the 5 kHz channelization plan in both the 150-174 and 450-470 MHz bands.

Table 3

Value of the 5.88 MHz of Extra Spectrum Created by Using 5 kHz Channelization (Based Upon Various Auction Results)			
1.9 GHz PCS Band MTAs at \$128.3M/MHz	218 MHz IVDS Band Cellular MSA/RSAs at \$248.7M/MHz	900 MHz PCS Band	
		Nationwide at \$783M/MHz	Regional at \$1.086B/MHz
\$0.8 billion	\$1.5 billion	\$4.6 billion	\$6.4 billion

The use of the 470-512 MHz band for land mobile radio is limited to 11 large cities. On average, each of the 11 cities has access to approximately two television channels. Subtracting an average of approximately 12 common carrier channels per television channel removes .6 MHz of spectrum from each of the 6 MHz television channels. Thus, PLMR users have access to approximately 5.4 MHz of spectrum per television channel. Using the

6.25 kHz spacing called for in the R&O/NPRM would produce 864 channels in this spectrum while the more spectrum efficient 5 kHz spacing would produce 1,080 -- a 216 channel increase for these largest markets. The 216 channels translate into 2.16 MHz of additional spectrum. Table 4 presents estimates of the value of this additional spectrum in the 11 cities.

Table 4

Value of the 2.16 MHz of Extra Spectrum Created by Using 5 kHz Channelization (Based Upon Various Auction Results) in the 470-512 MHz Band in the Larger Metropolitan Areas ⁶			
1.9 GHz PCS Band MTAs at \$128.3M/MHz	218 MHz IVDS Band Cellular MSA/RSAs at \$248.7M/MHz	900 MHz PCS Band	
		Nationwide at \$783M/MHz	Regional at \$1.086B/MHz
\$0.14 billion	\$0.27 billion	\$0.85 billion	\$1.2 billion

These results show that, based upon the previous auction results, the spectrum freed up by adopting the more spectrum-efficient technology in the 150-174 MHz and 450-470 MHz bands could be worth up to \$6.4 billion to the U.S. Treasury. The corresponding estimate for the 470-512 MHz band is \$1.2 billion for a grand total of up to \$7.6 billion. The previous auction results used here were for spectrum that could be used on an exclusive basis by the licensee. By employing those results in the calculations contained herein, we are

⁶ Based on the results of the 1.9 GHz PCS band auction of the two 30 MHz MTA A & B blocks of spectrum on a nationwide basis, we estimate that over half of the total amount of the winning bids was attributable to the approximate areas where the 470-512 MHz band spectrum is used by PLMR users. Thus, to estimate the value of the spectrum to the 11 cities, we took half of the value of spectrum per MHz on a nationwide basis, for each of the four auction results. Approximately 20 percent of the U.S. population is concentrated in the 11 cities. It should not be surprising that over half the value of spectrum on a nationwide basis can be attributed to these 11 major cities where UHF-TV spectrum is used by PLMR users, since spectrum congestion is greatest in these areas.

not necessarily advocating that the additional spectrum be auctioned and allocated on an exclusive basis. Rather, we are using the auction results merely as a proxy for the value of spectrum that would be made available.

VI. Other Economic Values Associated With a 5 kHz Channelization Plan

The additional spectrum freed up by the adoption of the more spectrum-efficient band plan advocated by Securicor would also have other potential economic benefits in terms of opportunities for (a) added jobs in the land mobile radio service sector, (b) added equipment sales, (c) new manufacturing jobs, and (d) serving added customers.

One can make an estimate of the number of new service jobs created by the 5 kHz channelization of the two primary bands by using statistics from the cellular industry and estimates for the SMR industry. For calendar year 1994, the cellular industry had revenues/employee of \$303k/yr.⁷ A representative figure for the SMR industry should be around \$100k. The following table presents estimates of the numbers of additional service jobs the 5 kHz channelization would provide over and above that provided by the R&O/NPRM's channelization.

⁷ Cellular Telecommunications Industry Association, "1994 Wireless Industry Survey Results: 'American Success Story' Continues," News Release, March 13, 1995.

Table 5

Number of Subscribers on Additional Channels (See Table 12 below)	Yearly Airtime Revenue Based on \$20 ⁸ Per Month	Total Yearly Revenue	Extra Service Jobs Created by 5 kHz Channelization Instead of the R&O/NPRM's Channelization	
			Based on the Cellular Industry Yearly Revenue of \$303k Per Employee	Based on an Estimate for the SMR Industry Yearly Revenue of \$100k Per Employee
3.65M	\$240	\$876 million	2,870	8,700

These results show that nearly 3,000 new service jobs could be created by adopting the more efficient channelization plan based on the cellular industry figures and nearly 9,000 jobs based on the estimate for the SMR industry.

To estimate the number of manufacturing jobs that could potentially be created because of the additional infrastructure equipment needed to equip the added channels created by use of the 5 kHz channelization in the 150-174 and 450-470 MHz bands, we make use of Motorola's 1991 total revenues per employee⁹ of (\$11.341 billion)/(102,000 employees) or

⁸ This airtime monthly revenue estimate was conservatively based on reported results for the SMR industry (American Mobile Telecommunications Association, News Release, November 30, 1994). For 1994, this source gives an average monthly bill for dispatch units of \$14.60 and \$52.70 for the roughly 21 to 25 percent of the installed base for interconnected units. Using the 75/25 percent ratio for the dispatch units and interconnected units respectively, one obtains an average monthly bill for all units of \$24.13. As a conservative average monthly airtime revenue we used the indicated \$20 per month.

⁹ Fairchild's Electronic Industry Financial Directory, 1992/1993.

more than \$110k. Table 6 presents results of the estimates of additional manufacturing jobs for the added infrastructure resulting from the use of 5 kHz channelization.

Table 6

Number of Subscribers on Additional Channels (See Table 12 below)	Number of Subscribers Per Channel	Number of Equipped Base Station Channels	Cost of Base Station Equipment Per Channel ¹⁰	Total Infrastructure Cost	Extra Year-Long Manufacturing Jobs Assuming Annual Sales Revenues of \$110k Per Employee
3.65M	50	73,000	\$10,000	\$0.73 billion	6,640

Table 7 presents estimates of additional manufacturing jobs resulting from the manufacture of the extra user terminals for the additional channels resulting from 5 kHz channelization instead of the R&O/NPRM's channelization. These figures are extremely conservative due to the fact that the transition to narrowband technology will take place over a long period of time. During this period, replacement units will be required, but they are not included in the estimates contained in Table 7.

¹⁰ This cost estimate is based on the present SMR industry.

Table 7

Number of Additional Subscribers	Cost of Subscriber Terminal	Total Cost of Extra Subscriber Terminals	Extra Year-Long Manufacturing Jobs Assuming Annual Sales Revenues of \$110k Per Employee
3.65M	\$600	\$2.19 billion	19,900

Table 8 combines the results of the above two tables.

Table 8

Number of Additional Subscribers	Total Cost of Extra Equipped Base Station Channels and Subscriber Terminals Resulting From 5 kHz Channelization Instead of the R&O/NPRM's	Extra Year-Long Manufacturing Jobs Assuming Annual Sales Revenues of \$110k Per Employee
3.65M	\$2.9 billion	26,500

These results show that almost \$3 billion in equipment sales could be generated and over 26,000 additional year-long manufacturing jobs could be created using the added spectrum.¹¹

¹¹ Under the R&O/NPRM's type acceptance strategy for transitioning to the new narrowband technologies a period of perhaps 10-20 years may be required for such a transition to fully occur. Accordingly, it is likely that many equipment replacements will be

Reasonably equating the increase in the number of possible users to the increase in the number of new channels created by the 5 kHz band plan gives the result of being able to accommodate substantially more users than that provided by the R&O/NPRM. This is only for the two primary frequency bands, i.e. the 150-174 and 450-470 MHz bands. One can now estimate how many additional users can be accommodated nationwide by comparing the present use of the cellular spectrum with the possible use of spectrum in these two bands.

The tables below present some preliminary data/estimates:

Table 9

Cellular System Data, Based In Part on CTIA Data					
Date	Number of Subscribers	Number of Cell Sites	Estimated Area Coverage of U.S. Cellular Systems (60% of area of U.S.)	Average Area per Cellular Cell Site	Average Cellular Cell Site Radius
Dec. 1994	24.1M	17.9k	2.16M sq mi	120.7 sq mi	6.2 mi

Table 10

Additional Data (The first three columns are from CTIA data)			
1994 Cellular Revs.	Average Number of Cellular Employees in 1994	Average Cellular Revenue/Employee in 1994	Estimated Average 150-174 and 450-470 MHz Band Base Station Coverage Radius
\$14.2 billion	46.8k	\$303k	16 mi

needed over this period of time, so that the presented figures may be very conservative.

Further data and estimates are provided in Table 11.

Table 11

Service or Frequency Band	Amount of Spectrum (MHz)	Total Number of Voice Equivalent Channel Users at End of 1994 (M)	Average Cell Radius (Miles)	Users Per Channel Per Base Station	Spectrum Per Channel ¹² (kHz)
Cellular	50	24.1	6.2	35	60
150-174 & 450-470 MHz Bands	23.845 MHz	14.8 ¹³	16	50	10

If we now assume that the coverage areas for the cellular systems and the other two bands in the above table are roughly the same, and logically, that the distribution of the density (and not the density itself) of base stations is comparable in both kinds of systems, we can estimate the total number of voice equivalent bandwidth channel users by scaling the cellular results as follows:

Number of voice equivalent channel users that can be accommodated in the 23.845 MHz of PLMR spectrum in the two bands = (50 band users/channel/base station)/(35 cellular users/channel/base station) x (24.1 M cellular users) x (23.845 band MHz/50 cellular MHz) x (60 kHz per cellular channel/10 kHz per band channel) x (6.2 mi cellular cell radius/16 mi band cell radius)² = 14.8M.

These calculations show that the reformed spectrum using 5 kHz channelization can be expected to support 14.8M users. Earlier, we estimated that the 5 kHz channelization would

¹² The assumption is that all the cellular customers today are served by AMPS systems.

¹³ This figure was estimated from the remaining information in this table.

increase the number of channels by 32.7% over the number achievable under the R&O/NPRM's channelization plan. Thus, the R&O/NPRM's channelization could be expected to support 14.8M/1.327 or 11.2M users. Accordingly, the 5 kHz channelization plan would support 14.8M - 11.2M or 3.6M more users than what the R&O/NPRM's channelization plan would support. The following table summarizes the above results:

Table 12

Using R&O/NPRM's Channelization		Using 5 kHz Channelization		Extra Paired Channel Capacity Created By 5 kHz Channelization Over the R&O/NPRM's Channelization		Capacity Increase From Using 5 kHz Channelization Instead of the R&O/NPRM's (%)
Number of Channels	Number of Subscribers	Number of Channels	Number of Subscribers	Number of Channels	Number of Subscribers*	
1,797	11.18M	2,385	14.8M	588	3.65M	32.7

The number in the column indicated with an asterisk was used in the calculations contained in Tables 5-8.

VIII. Estimate of the Contribution of Private Land Mobile Radio to the Economy

Increasingly it is being recognized that wireless communications has a strong impact on the economy of a country. An economic impact study for the U.K.¹⁴ claims the use of

¹⁴ This information was gleaned from two slides used by Jim Norton, the CEO of the Radio Communications Agency, in a presentation he made in London in 1995.

radio contributes more than £10B to the GDP, an employment of 300,000 plus, and consumer and efficiency benefits of £7-10B plus.

Broken down by mobile and non-mobile categories, upper range estimates for consumer and efficiency benefits of radio in 1993 were: broadcasting -- £3B; cellular -- £5B; private mobile radio --£ 2.25B; and fixed links -- £0.4B, for a total of £10.6B. The range of estimates for the total consumer and efficiency benefits was given as £6.5-10.6B. Based on these upper estimates, private mobile radio contributes £2.25B/£10.6B or more than 21 percent of the consumer and efficiency benefits of radio and cellular mobile over 47 percent; thus, private and cellular mobile radio contribute over 68 percent to the consumer and efficiency benefits.

Assuming that the above private mobile radio percentage of consumer and efficiency benefits would apply to the more than £10B contribution of radio to the U.K.'s GDP, one can attribute £2.1B of the GDP to private mobile radio. Applying this same percentage to the more than 300,000 jobs attributable to the radio industry suggests that the U.K.'s private mobile radio industry involves the employment of about 63,000 people. Similar contributions can be estimated for the cellular mobile industry.

Scaling the above figures for the U.K. by the ratio of populations of the U.S. and the U.K. (approximate 5:1) we obtain estimates for the U.S. as shown in the table below.¹⁵

¹⁵ The conversion of U.K. pounds into U.S. dollars was made at the rate of 1.6 U.S. dollars per pound sterling.

Table 13

Wireless Industry	Estimated Contribution to the United State's		
	GDP	Consumer & Efficiency Benefits	Employment
Radio	\$80 billion	\$85 billion	1.5 million
Cellular	\$38 billion	\$40 billion	705 thousand
Private Mobile Radio	\$17 billion	\$18 billion	315 thousand

The contributions in the above table that can be attributed to the PLMR spectrum that the Commission is planning to refarm in the U.S. are uncertain; however, this spectrum clearly represents a substantial portion of the PLMR spectrum in the U.S. so that the contributions are clearly very substantial. In fact, according to the R&O/NPRM, para. 8, at the time of the refarming Notice of Inquiry there were 12 million licensed transmitters in the refarming bands and these transmitters constituted 66% of all of the nation's 18 million licensed PLMR transmitters.

Assuming that private mobile radio in the U.K. contributes approximately the same percentage of radio's contribution to the U.S.'s GDP, consumer and efficiency benefits, and employment as it does in the U.K., we conservatively estimate that only 50%, instead of the 66% in the Notice of Inquiry, of the PLMR licensed transmitters are in the refarming bands. This results in an estimate that the portion of the U.S.'s PLMR industry associated with the refarming bands contributes more than \$8 billion to the GDP, \$9 billion to consumer and efficiency benefits, and over 150 thousands jobs. While there are obvious limits in trying to

extrapolate the U.K. results to the U.S., the magnitude of these amounts does suggest the economic significance of the Commission's activities in the refarming bands.

VII. Summary and Conclusions

In the above analysis we have shown that there would be extremely favorable economic impacts if the more spectrum-efficient channel plan advocated by Securicor would be adopted instead of the one specified in the Commission's R&O/NPRM. These positive economic impacts are summarized in Table 14 for the 150-174 MHz and 450-470 MHz bands alone.

Table 14

Description	Economic Impact
Increase in the Number of Available Voice Channels in a Given Geographic Area	588
Increase in Treasury Revenues from Auctions	6.4 billion
Number of New Service Jobs	8,800
Value of Additional Infrastructure and Subscriber Terminals	\$2.9 billion
Number of New Manufacturing Jobs (Person-Years)	26,500
Increase in the Number of New Subscribers	3.6 million

Including the 470-512 MHz band would increase the extra number of available voice channels in the 11 largest cities from 588 to over 800 and the potential auction revenues to as high as \$7.6 billion. Further increases would be included in the other categories as well.

Finally, estimates developed in the U.K further suggest that the economic consequences of the Commission's activities relating to the refarming bands are enormous indeed.